The Engineered Concrete Bulkheads Installed by SGC

February 2018

I. EXECUTIVE SUMMARY

The installation of engineered bulkheads is often part of Best Management Practices for final mine closure. The engineered concrete bulkheads installed by SGC in the Bonita Peak area for purposes of environmental remediation are stable and performing as designed. As intended, and as approved by the State of Colorado and EPA, the bulkheads have isolated the interior workings of the Sunnyside Mine and caused the water table to return toward natural levels, resulting in the expected increase in flows from springs, seeps and adits. As recently recognized by multiple engineering experts, the engineered bulkheads are completely stable and there is no appreciable risk of catastrophic failure.

II. BULKHEADING OF MINES FOR ENVIRONMENTAL REMEDIATION

Placement of engineered bulkheads in draining mine adits for environmental remediation is a Best Management Practice for final mine closure. In the right geologic setting, this practice isolates mine drainage water from direct contact with surface waters, establishes an approximation of the pre-mining phreatic surface, and minimizes the oxygen available for chemical reaction. An added benefit of engineered bulkheads is the protection of surface waters from blowouts caused when flow blockages occur due to collapsed and unmaintained mine workings that may be suddenly released when internal pressure exceeds the structural capabilities of the blockage.

The reestablishment of the pre-mining phreatic surface allows waters to return to their pre-mining flow paths emerging as seeps and springs that existed prior to mining, rather than draining through exposed mine workings. The seeps and springs that are located away from surface flows most likely undergo metals reductions when oxygenated after surfacing and migrating towards surface flow paths, creating ferricrete deposits that exist naturally in mineral rich environments.

For a general discussion of the positive impacts of bulkheading, please see information contained at http://www.miningfacts.org/Environment/What-is-acid-rock-drainage/. Additionally, the Global Acid Rock Drainage (GARD) Guide discusses, at length, the benefits of the well-reasoned use of bulkheads. For example:

> When decommissioning an underground mine, knowledge of the areas within the mine that are geochemically most reactive and knowledge of water ingress and discharge locations will enable design and implementation of a rational ARD management plan aimed at controlling the flow of water to minimize water quality deterioration. This process would involve construction of seals [bulkheads] and also perhaps reinforcing of some areas in advance of flooding to accommodate water flow. Use of seals and reinforcements is a good example of prevention and minimization by design. See http://www.gardguide.com/index.php?title=Chapter_6

Furthermore, as noted in the March 2016 Deere & Ault report commissioned by EPA:

> Water impounding concrete bulkheads installed at strategic locations in draining and discharging underground mine workings have the potential to flood the workings and create a mine pool that will eventually establish a ground water system with water table and flow paths similar to the pre-mining system. Saturation of sulfide minerals in the flooded workings and country rock will create relatively anoxic conditions and limit the generation of ARD. Bulkhead installation eliminates rapid and continuous collection and discharge of ground water through open mine workings and minimizes direct discharge of ARD from mine portals....Bulkhead installation in mines that are determined to be good candidates has the potential to significantly reduce metal loading to receiving streams. (May18, 2015 DRMS report at 1-2).

Without question, in mines such as the Sunnyside Mine, bulkheads are a crucial component of safe and effective environmental remediation.

III. THE ENGINEERED BULKHEADS INSTALLED BY SGC

A. Description of the Engineered Bulkheads.

Numerous engineered bulkheads have been installed in the Bonita Peak area specifically for the purpose of environmental remediation. SGC installed nine engineered bulkheads in connection with the closure of the Sunnyside Mine between January 1994 and November 2001. EPA has since recently installed a bulkhead at the Red and Bonita Mine.

Three of the SGC-installed engineered bulkheads were placed within the American Tunnel, the lowest drainage pathway from the interior workings of the Sunnyside Mine to surface. The most interior American Tunnel bulkhead (Bulkhead #1) was placed to isolate the interior mine workings from the surface. This bulkhead also isolates the SGC owned property from downstream portions of the American Tunnel owned by others. The next interior engineered bulkhead (Bulkhead #2) was placed down gradient of a water-bearing fracture zone to isolate the flows from this zone and return them to their natural path. The most near-surface engineered bulkhead (Bulkhead #3) is on BLM ground and was placed to capture water entering the American Tunnel from the near-surface fracture system.

Two of the SGC-installed engineered bulkheads were placed in the Terry Tunnel, the upper level main drainage pathway from the interior workings of the Sunnyside Mine to the surface. The interior engineered bulkhead was placed to isolate the interior mine workings from the surface. The near-surface bulkhead was placed to isolate any in-flows to the tunnel downstream of the interior bulkhead.

Additionally, SGC installed four engineered bulkheads to isolate the interior workings of the Sunnyside Mine from the Brenneman and Mogul workings.

B. Engineering and Installation of the Bulkheads.

The engineered bulkheads installed by SGC were all designed by John F. Abel, Jr. PhD, a retired professor from the Colorado School of Mines. The engineered bulkheads were designed as reinforced concrete deep beam structures using American Concrete Institute Code Requirements. This same design was largely utilized by EPA for the Red and Bonita bulkhead. The SGC-installed bulkheads were designed for maximum possible head (surface elevation), using appropriate construction materials for the exposure conditions and the environment. Each of the SGC-installed engineered bulkheads was specifically designed to be stable for any predictable earthquake loading.

As part of the installation process, Dr. Abel did a pre-pour inspection on all bulkheads and was on-site during the majority of the concrete pours. Expert experienced underground miners conducted the installation. Colorado's Division of Reclamation Mining and Safety (DRMS) also did a pre-pour inspection on each of the bulkheads. DRMS commented that the locations chosen were ideal for bulkhead installation.

C. The 1996 Consent Decree

SGC was formed and acquired the Sunnyside Mine in 1985 and mined it from 1986 until 1991 using modern techniques and under the modern era of environmental regulation. Due to state and regulatory approval, and approval from engineering experts, it was clear that the installation of engineered bulkheads was perfectly suited as a Best Management Practice for final closure of the Sunnyside Mine. It was recognized that the engineered bulkheads would return the water table toward natural levels, resulting in an expected flow increase from springs and seeps. A legal question arose as to the permitting of these resulting increased flows. As part of the resulting legal process, and aware that bulkheading would cause additional flows elsewhere, SGC and the State of Colorado entered into a comprehensive settlement agreement that took the form of a Court-approved Consent Decree. The installation of engineered bulkheads in the American and Terry Tunnels was required by the Consent Decree. In consideration of SGC's installation of these bulkheads and related remediation activity, Colorado, acting under EPA vested authority, agreed not to sue or take any administrative action against SGC for future seeps or springs that might emerge or increase as a result of SGC's activities. EPA had a significant role in the Consent Decree's development and implementation. EPA encouraged the Consent Decree and applauded its results. EPA's retained expert on the issue stated "Technically, the plan [utilized in the Consent Decree] makes sense and has merit, and I encourage its implementation without further, long-term discussion." SGC completed all of the requirements of the Consent Decree, which included the installation of the engineered bulkheads in the American and Terry Tunnels and, in 2003, the Court discharged SGC's remedial obligations with respect to the Sunnyside Mine.

D. The Engineered Bulkheads are Stable and Performing as Designed

It is clear that the SGC-installed bulkheads are stable and performing as designed, and no further study is necessary to support this fact. Multiple experts have recently reviewed the bulkheads in the American Tunnel, which are considered the most critical. These experts, including experts retained by EPA, have concluded that the bulkheads were well-constructed, are working as designed, and that catastrophic failure leading to a large release of water is extremely unlikely.

For example, a 2016 Deere & Ault study commissioned by EPA concluded that "Shear failures in the bulkheads are highly unlikely . . . [and that] …[s]tructural failures would be very unlikely." The report specifically stated:

> We have reviewed the design and as-built reports for all three American Tunnel bulkheads and generally concur with their stated capacities. . . . Based on their design pressures, the American Tunnel Bulkheads are unlikely to fail in a catastrophic manner. If water pressures were higher than expected, the most likely consequence would be increased seepage past the bulkheads and through the rock mass.

Further, attached hereto as Exhibit A is a report recently prepared by Stephen Phillips of Phillips Mining Geotechnical & Grouting LLC. Mr. Phillips has extensive, worldwide experience with bulkheads and is a leading expert in the field. His report discusses in detail the design and construction of the American Tunnel Bulkheads and reaches the same conclusion as Deere & Ault: "It is my opinion that the design and construction of the bulkheads were carried out adequately and that a catastrophic disruptive shear failure leading to a large release of water is extremely unlikely." Further, Mr. Phillips specifically concludes that, because the bulkheads were constructed to "potential head conditions", further study on the likelihood of a catastrophic failure would be unnecessary and unwarranted.

IV. CONCLUSION

The engineered concrete bulkheads installed by SGC in the Bonita Peak area for purposes of environmental remediation are stable and performing as designed. As intended and designed, and as approved by the State of Colorado and EPA, the engineered bulkheads have isolated the interior workings of the Sunnyside Mine and have returned the water table toward natural levels. This has resulted in the expected increase in flows from springs and seeps which has, as anticipated, increased flows from unbulkheaded adits. There is no credible evidence to the contrary. The engineered bulkheads are completely stable, and, as recognized in the recent written opinions of multiple experts, there is no appreciable risk of catastrophic failure. Any suggestion to the contrary would be baseless and irresponsible.

Exhibit A

To

The Engineered Concrete Bulkheads Installed by SGC

THE AMERICAN TUNNEL BULKHEAD STABILITY ANALYSIS AND REPORT

Prepared for:

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FEBRUARY 2018

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THE AMERICAN TUNNEL BULKHEAD STABILITY ANALYSIS AND REPORT.

1. INTRODUCTION

I have been asked to evaluate certain existing data (described herein) and offer an opinion as to the stability of the bulkheads in the American Tunnel, and specifically, the likelihood of a catastrophic bulkhead failure, as defined as an "in tunnel" disruptive shear or structural failure of the bulkhead leading to a large release of water.

The construction of the three bulkheads in the American Tunnel was a mitigation project completed as part of a "Consent Decree" involving Sunnyside Gold Corporation and the State of Colorado aimed at segregating the Sunnyside Mine workings from other workings in the area and minimizing the flow of mine-impacted water from the American Tunnel to Cement Creek. The purpose of these three bulkheads, together with other bulkheads built previously in interconnected mine workings, was to restore the post-mining hydrology as best as possible to that which existed prior to mining. The bulkheads were designed and located to prevent the movement of groundwater through the low resistance mined openings as was occurring prior to the bulkhead construction.

As well as minimizing the flow of water through existing mine workings, it was intended that impounding the water would significantly reduce the oxidation rate of sulfide minerals that were previously exposed to air in the abandoned stopes, drifts and tunnels. This process would minimize the eventual production of sulfuric acid and the metallic and sulfate ion contamination of the water draining from the American Tunnel.

This review is based mainly on annotated projections of the Sunnyside Mine, on a report and a letter report, both authored by Dr. John F. Abel Jr. entitled, "Bulkhead Design for the Sunnyside Mine" dated March 10, 1993 and, "American Tunnel Bulkheads #2 and #3", dated January 15, 2001, respectively. The reports, drawings and other miscellaneous data and exchanges were provided by Sunnyside Gold Corporation personnel, at least one of whom was active in the construction of the bulkheads.

The American Tunnel was originally driven (by others) 6,233 feet northeastward from the portal as a deep level exploratory and potential development access for the Gold King Mine. The American Tunnel was never connected to the Gold King Mine workings about 850 feet above the Tunnel (see Attachment 1, showing the location of the American Tunnel relative to other mine workings in the area). Between 1960 and 1961, the tunnel was extended to the Sunnyside Mine workings to provide egress, ventilation, and ore haulage for that mine. The approximate portal elevation is 10,600 feet and the total length of the tunnel is approximately 10,450 feet (Reference 1).

The first of the three bulkheads to be constructed in the American Tunnel was Bulkhead Number 1 at elevation 10,668 feet. This bulkhead was placed near Sunnyside's property boundary. The ground cover over the bulkhead at this location is about 2,130 feet and the hydrostatic head used in its design was 1,550 feet (670 psi). This bulkhead is 25 feet long and located 7,950 feet from the American Tunnel portal and about 500 feet downstream of two ore passes (likely to be at least partially plugged) that connect the American Tunnel to upper levels of the mine, and 2,486 feet downstream from a shaft station. There are no other mined connections to the upper levels of the mine between these two ore passes and the American Tunnel Portal.

From private communications (Reference 2), the water flow through the portion of the tunnel where Bulkhead Number 1 is located was relatively steady throughout the year at about 1,700 gpm. After completion of this bulkhead in 1996, the hydrostatic head buildup behind the bulkhead was monitored for 5 years until steady state was reached. At this time, the phreatic level in the mine had risen to elevation 11,666 feet, resulting in a hydrostatic head of 998 feet (432 psi) on the bulkhead. In 2002, the State of Colorado noted that "the mine tunnel seal in the American Tunnel, initially placed in 1996, has functioned and continues to function as designed while the mine pool has risen behind the plug to the point of physical equilibrium."

The next bulkhead to be constructed was Bulkhead Number 2, some 5,950 feet downstream (closer to the American Tunnel Portal) from Bulkhead Number 1. The ground cover over the bulkhead at this location is 762 feet and the hydrostatic head used in its design was 640 feet (277 psi). This bulkhead is 10 feet long and was constructed to impound leakage, if any, through or passing around Bulkhead Number 1 together with any water that was produced over the 5,950 feet of tunnel between the two bulkheads. The majority of the total inflow of about 850 gpm of water that was impounded by Bulkhead Number 2 issued from a 200+ feet wide fractured/faulted zone that itself produced about 650 gpm.

Bulkhead Number 2 was completed at the end of August 2001 when the valve on the drainage pipe was closed. The last time the pressure on this bulkhead was recorded, 8.5 months after its completion, the hydrostatic head on it was 376 feet (163 psi) and leakage through or passing around the bulkhead was reported as being minimal. Based on the recorded build-up of head on this bulkhead with time and extrapolating the data, it is considered most unlikely that under the same conditions, the final steady state hydrostatic head exceeded 392 feet (170 psi).

Prior to the construction of Bulkhead Number 2, it was anticipated that some time after its completion and the buildup of hydrostatic head behind it, there might be an increase in flow in Cement Creek. The mechanism for this potential increase was water flow from the pressurized section of tunnel up to surface through the relatively permeable 200 feet wide fractured/fault zone located 1,000 to 1,200 feet upstream of Bulkhead Number 2. Not surprisingly, this flow increase was not observed because the final head on the bulkhead was insufficient to raise the phreatic head some 640 feet up to the ground surface.

The third bulkhead (Bulkhead Number 3) was constructed 1,625 feet downstream from Bulkhead Number 2 and is located 375 feet from the American Tunnel Portal. The ground cover over the bulkhead at this location is 160 feet and the hydrostatic head used in its design was 773 feet (335 psi). This bulkhead is 11 feet long and was constructed to impound the water produced in the tunnel from "generalized increased joint permeability" in the rock between it and Bulkhead Number 2. From the available records, this produced water amounted to about 450 gpm.

Shortly after the completion of Bulkhead Number 3 in December 2002, the portal of the American Tunnel was backfilled around a pipe that was installed to drain any water finding its way into the 375 feet of tunnel between the bulkhead and the portal. Thus, there was only access to this bulkhead for a short period of time and no direct long-term monitoring or observation of its performance.

Sometime in 2003, the portal of the American Tunnel was reopened and additional grouting was carried out. The report on site reclamation activities for the period April 2003 to March 2004 records this as follows. "Reopening the American Tunnel and performing maintenance work (grouting) of the American Tunnel downstream of the No. 3 Bulkhead. Seepage from the remaining tunnel occurred after closure, as the water table in the mountain was re-established. The remaining tunnel provided a path for the near surface fracture system to drain to surface. Work on this project was not completed due to winter conditions."

Currently, there are three engineered bulkheads in the American Tunnel between the Sunnyside Mine's boundary and the American Tunnel Portal. The location of the American Tunnel bulkheads is shown in Attachment 2.

2. BULKHEAD STABILITY AND FAILURE DESIGN CONSIDERATIONS.

In most situations, the optimum shape for an underground bulkhead is one with parallel sides that conforms to the cross section of the existing excavation, as documented by Garrett and Campbell Pitt, Lancaster (References 3, 4 and 5) and more recently by Auld (Reference 6). In most drill and blast excavations, the surface of the exposed rock is very irregular and so it is not necessary to provide additional load transferring devices such as tapers or hitches. A parallel-sided bulkhead requires the minimum of additional excavation and is usually the simplest type of bulkhead that satisfies the necessary design requirements for a bulkhead.

To help ensure the integrity of a bulkhead, maximize its effective life and protect public safety and the environment, a bulkhead design should incorporate the following features;

- Optimize its location. The long-term performance of any bulkhead depends greatly upon the choice of bulkhead location and should be constructed at the most appropriate site to achieve the desired performance. The optimum bulkhead location is one in which the conditions are stable, the surrounding rock is competent, has a low permeability, is preferably in an area of low seismic activity and is free from major geological features such as faults, shear zones, veins, etc. In addition, the bulkhead site should be remote from highly stressed areas and other mined openings. It is not always possible to find the perfect bulkhead site. However, an imperfect site may become acceptable by modifying the bulkhead configuration or the ground treatment around it, and/or employing higher factors of safety to accommodate the existing conditions.
- Use appropriate factors of safety. Bulkhead designs should be based on the "best available technology" and appropriate factors of safety that result in the most effective closure for the actual site conditions. In particular, it is important to ensure the following:
    - That the bulkhead structure itself can withstand the stresses applied to it under both normal operating conditions and those associated with potential seismic events.
    - That the stresses on the contact between concrete and rock are within the allowable limits for the weaker material, such that the bulkhead can safely generate the necessary shear resistance to withstand the applied hydrostatic head.
    - That the hydraulic gradient across the bulkhead is sufficiently low such that leakage around the bulkhead is minimal.
- Use appropriate techniques and durable materials in the bulkhead construction. Bulkheads that are used to impound water should be designed and constructed to

minimize leakage from the flooded mine through and around the bulkheads and be resistant to chemical attack by any deleterious substances or aggressive water that is impounded by it.

To achieve these objectives, particularly for a long-term mine closure, the design approach adopted should incorporate appropriate factors of safety and use the most suitable techniques and durable products that are in current use to minimize the potential degradation of the bulkhead in the environment in which it has to function.

3. AMERICAN TUNNEL BULKHEADS.

3.1 Bulkhead Location

According to Dr. Abel's reports, the bulkhead locations were chosen to maximize the length of natural low resistance hydraulic flow paths (the mined openings) and to minimize the potential for water leakage through the jointed rock adjacent to the bulkheads.

From the available information, it appears that there are no major geological features present at or near any of the American Tunnel Bulkheads. The closest major feature appears to be a fault that is located between Bulkhead Numbers 1 and 2, and that is about 4,800 feet downstream from the former and 1,000 feet upstream of the latter bulkhead.

The three bulkheads in the American Tunnel are all remote from the nearest mine opening. The lowest level of the Gold King Mine is about 850 feet vertically above the central section of the American Tunnel and any significant workings of the Sunnyside Mine working are over 2,000 feet inby of Bulkhead Number 1 and several hundred feet above.

According to the records, the three locations in the American Tunnel chosen as the sites for the bulkheads were generally dry, thus indicating that the rock at the three sites had relatively low permeability.

Based on the descriptions of the conditions at the three sites chosen for the American Tunnel bulkheads, he choice of the bulkhead sites was appropriate to achieve the desired performance and will not have adversely influenced their long-term performance.

3.2 Factors of Safety.

The three American Tunnel bulkheads were designed as parallel sided, reinforced concrete bulkheads. The choice of parallel-sided bulkheads was very appropriate for those to be constructed in the American Tunnel. Parallel-sided bulkheads achieve resistance to the applied wet end hydrostatic pressure through mechanical interlock with the rough excavation face of the surrounding rock and can be constructed with just plain or reinforced concrete. The plain concrete bulkhead must be long enough such that the bending stresses in the concrete at the downstream end of the bulkhead do not exceed the allowable flexural tensile strength of the concrete. The reinforced concrete bulkhead incorporates steel reinforcing bars placed close to the downstream end of the bulkhead to carry the flexural tensile stresses. In general, parallel sided, reinforced concrete bulkheads are shorter than parallel sided, plain concrete bulkheads unless the bulkhead length is dominated by other controlling factors.

Table 1 provides details of the design parameters for the three bulkheads and includes the various design Factors of Safety against structural failure and leakage given in the design documents. The concrete mix design chosen for the bulkheads had an unconfined compressive strength of 3,000 psi. The concrete strength controls the shear analyses because of the higher rock strength as determined from tests performed at the American Tunnel Bulkhead Number 1 site. At this site the rock strength ranged from 3.5 to 8 times the concrete strength.

The design factors of safety on the structural aspects of the bulkheads conform to the American Concrete Institute ACI Building Code Requirements for Reinforced Concrete ACI 31889. This required the use of the appropriate strength reduction factors together with the requirement that intensifying factors be applied to the maximum dead or fluid load that is resisted by the reinforced concrete deep beam structure. The design for the critical deep beam flexural stresses is based upon either vertical or horizontal rebar (whichever span is the larger) but in practice these stresses are resisted by two-way (both horizontal and vertical) rebar reinforcement, thus essentially doubling these design factors of safety.

The design earthquake loading on the bulkheads is based on the sum of the mass of water that has line-of-sight path to the bulkhead and the mass of the bulkhead itself that are accelerated by 0.087g maximum credible horizontal earthquake component. The ACI earthquake design procedure for reinforced concrete structures was used to determine the actual structural requirements of the bulkheads to resist the earthquake loading. Subsequently, in 2014, the maximum potential earthquake acceleration for the regional setting of the Sunnyside Mine was upgraded. This area was designated by USGS as a zone with a Seismic Hazard of 2% probability of exceeding a peak ground acceleration of 14-20% g (0.14g to 0.2g) in a 50 year period (Reference 7).

Three “rings” of holes were specified in the design report to be drilled relatively equally spaced (about 6 feet apart) along the 25 feet length of Bulkhead Number1. Each “ring” was to consist of 7 holes, 3 in the back and 2 in each side with a spacing of about 5 feet between holes. No holes were specified to be drilled to the concrete/rock contact in the floor. Based on the grout hole requirement for other relatively short bulkheads installed in the Sunnyside Mine and designed by Dr. Able, it seemed likely that the American Tunnel Bulkheads Numbers 2 and 3 would have only one “ring” of 7 similarly spaced holes that intercepted the concrete/rock contact in the back and ribs in the center of the 10 and 11 feet long structures.

The order in which the holes were to be drilled and grouted was not specified, only that they were to be drilled to the concrete/rock contact and grouted. Grout mix designs were not mentioned, but cement was to be used. No cement type was specified. Grouting pressures for Bulkhead #1 could range between a minimum of 100 psi and a maximum of 500 psi whereas grouting pressures for the other two American Tunnel bulkheads were not specified (possibly between 100 and 200 psi, based on that quoted for other relatively short bulkheads installed in the Sunnyside Mine and designed by Dr. Abel).

Grouting was specified to continue until refusal at the selected grouting pressure, but not less than the minimum specified 100 psi. If grout acceptance continued after the injection of two bags of cement without reaching the minimum grout pressure, grouting was to be continued in a new hole. If grouting in any one hole was deemed unsatisfactory, it was to be redrilled and re-grouted one day later. The process of cycling through the holes on each bulkhead had to continue until grout pressure either built up to the minimum pressure, or grout leaked at the free bulkhead face.

At the completion of the grouting, the holes were to be filled with grout and abandoned.

Based on the grouting program that was specified and applied to just the concrete/rock contact and the grouting pressures that would be used, it was established that the bulkhead should be capable of withstanding a hydraulic gradient of 41 psi/ft with minimal leakage.

Table 1. Design Factors of Safety on Structural and Leakage Aspects of the American Tunnel Bulkheads

B'head	Design Length (feet)	Design Head (feet) [psi]	F.S.* Design Hydraulic Gradient	F.S. Critical Section Shear	F.S. Rock/ Concrete Contact Shear	F.S. *** E'quake Outby (Inby)	F.S. Deep Beam Bend Stress
#1	25	1550 [670]	1.53	1.48	1.26	1.26 (****)	1.01
#2	10	640 [277]	1.48**	1.48	1.16	1.204 (1.12)	1.03
#3	11	773 [335]	1.35	1.51	1.08	1.24	1.02

* Based on allowable hydraulic gradient of 41 psi/foot

** Arithmetic error, actual F.S. is 1.41.

*** Quoted F.S. based on earthquake acceleration 0.085g.

**** This value not given.

As noted in Dr. Abel's reports, the ACI code requires the application of strength reduction factors for reinforced concrete in flexure resulting in an actual minimum factor of safety of 1.56 against flexure. In addition, the design for the deep beam flexural stresses is based upon either vertical or horizontal rebar (whichever span is the larger), but in practice these stresses in bulkheads are resisted by two-way (both horizontal and vertical) rebar reinforcement, thus essentially doubling these design factors of safety.

In the case of shear, these ACI required factors result in an actual minimum factor of safety against shear of 1.65. These built-in factors of safety are not reflected in the quoted factors of safety given in Table 1, thus effectively increasing the relatively low values quoted there for flexural and shear stresses.

These modifications to the factors of safety that provide actual factors of safety apply not only to the deep beam bending stresses, but also to earthquake loading. Under these conditions the latter factors of safety are acceptable even under the new, increased, maximum potential earthquake acceleration designated by USGS in 2014 for the regional setting of the Sunnyside Mine.

3.3 Appropriate Techniques and Durable Products.

As noted above, the American Tunnel Bulkheads should be designed and constructed using applicable methods and be resistant to chemical attack by the aggressive water that is impounded by them. To achieve this outcome, particularly for a long-term mine closure, the most appropriate techniques and available, durable products must be used to minimize the potential degradation of the bulkhead.

Preparation for bulkhead construction included the installation of a coffer dam and appropriately sized pipe to control any water flowing through the bulkhead site, removal of the track, ties and all the rock ballast, scaling loose rock down to solid, and washing the rock surface to remove dirt and debris.

The main component of the bulkheads, the concrete, was specified to consist of a mix using OPC Type V, sulfate resisting cement to withstand the chemical attack by the sulfate ion concentration of the impounded mine water as required by the ACI code for exposure of concrete to “moderate” sulfate concentrations from 500 ppm to 1,500 ppm. The sulfate ion concentration in the mine water was approximately 1,040 ppm (Simon HydroSearch 1992 Appendix D). In addition to using Type V cement, the concrete mix design specified a water:cement ratio of 0.45 by weight and the addition of fly ash pozzolan in the amount of 16 percent of the cement by weight. The fly ash decreases the permeability of the cast in place concrete and thus improves its resistance to chemical attack. These concrete mix components were specified to further improve the durability of the concrete and its sulfate resistance to be in accordance with the ACI code requirements for concrete in contact with "very severe" (greater than 10,000 ppm) sulfate ion concentrations.

The design concrete mix proportions were 1:2.5:3.5 cement:sand:gravel, the gravel being well graded ¾ inch maximum coarse aggregate. The relatively large amount of sand in the mix was specified to increase the slump of the mix, thus improving pumpability and to facilitate the filling of the bulkhead forms and the ability of the concrete to readily flow under gravity through the rebar mats. The use of the ¾ inch maximum aggregate size was also specified to enhance pumpability and minimize segregation and honey combing, particularly between the rebar mat and the face of the bulkhead forms. The class and quality of the fly ash was not specified in the design report.

4. COMMENTS.

Based on the descriptions of the conditions at the three sites chosen for the American Tunnel bulkheads, it is considered that the choice of the bulkhead sites were appropriate to achieve the desired performance and will not have adversely influenced their long-term performance.

The choice of parallel-sided bulkheads was very appropriate for those to be constructed in the American Tunnel. The factors of safety on the structural aspects of the bulkheads are adequate. This conclusion is further emphasized by three other considerations that effectively increase some of the actual, in-situ factors of safety;

- Although the factors of safety on deep beam flexural stresses appear low, the calculations to ACI code contain some built-in safeguards and for these bulkheads is based upon either vertical or horizontal rebar (whichever span is the larger). However, in practice, in the design of these bulkheads, these stresses are resisted by two-way (both horizontal and vertical) rebar reinforcement, thus effectively doubling the factors of safety.

- Based on the results of testing the concrete cylinders taken for each bulkhead, the average unconfined compressive strength of the concrete was at least 50% higher than that used in the design (Private communication, Reference 2).
- The design hydrostatic head on at least Numbers 1 and 2 Bulkheads has not been achieved by a fairly significant margin (30 to 35% less) based on the available information.

The recommended preparation of the bulkhead sites prior to erecting the concrete forms and concreting was very thorough. The water flowing through the tunnel was controlled and piped through the construction area and the loose rock was scaled and rock surfaces that would be covered with concrete were cleaned.

The design report correctly requires that the concrete placement be one monolithic pour. The concrete mix used all the appropriate components and mix ratios to minimize its degradation by the acidic mine water that was to be impounded. Fly ash was used firstly to minimize the total quantity and rate of generation of the heat of hydration that is produced in the concrete and avoid the potentially detrimental thermal effects that may be produced during setting, and also minimize any thermal shrinkage. Secondly, the fly ash with the Type V cement comprises a durable cementitious paste that is resistant to the potentially acidic water retained behind the bulkheads. No thermal problems associated with the setting and curing of the concrete were reported. From private communications (Reference 2) it has been reported that Class F fly ash was appropriately used.

Even when the rock at a bulkhead site is very competent and has inherently low permeability, water will seep through any fractures or partings around the bulkhead as well as along the rock/concrete interface when the full hydrostatic head is applied. Thus, special precautions must be taken to minimize this occurrence. An integral part of the successful installation of an underground bulkhead for the impoundment of water is the grouting program that is performed around the bulkhead. This procedure is carried out to ensure that intimate contact is achieved between concrete and rock for the uniform transfer of stress and that the resulting bulkhead will exhibit the minimum of leakage.

Although the design reports give sparse detail on the grouting around the bulkheads, additional information has been obtained from private communications (Reference 2). A total of 31 holes in the 3 rings were drilled and grouted at Bulkhead Number 1. Grouting pressures up to 270 to 290 psi were used, but only a little grout was injected. The single ring of holes at Bulkhead Number 2 consisted of 9 holes, as did the ring at Number 3 Bulkhead. Pressures up to 200 psi were used at both bulkheads. Not much grout was injected around Bulkhead Number 2, but some holes at Bulkhead Number 3 accepted grout and could not be pressured up initially and had to be re-drilled and re-injected later. Type V cement was used for the grouting as was appropriate from the perspective of durability.

The grouting performed on the American Tunnel bulkheads will have significantly reduced the leakage along the concrete/rock contact and through fractures in the rock adjacent to it. This is evidenced by the reported minimal leakage through and passed Bulkheads 1 and 2, even when what is believed would be the maximum head (or close to it) was being applied to these bulkheads.

From private communications (Reference 2) it has been determined that the pipes and fittings were suitably fabricated from stainless steel. Additionally, filling and sealing of the drainage pipes and the monitoring pipe (for Bulkhead Number 1) was carried out appropriately, using a pig to displace the water in the pipe ahead of it, and so allowing the pipe behind it to be completely filled with grout, without any possibility of water mixing with the grout. Thus, if a zero-bleed grout was used, complete filling and sealing of the pipe would have been achieved. If there was any doubt about this, the use of stainless steel for the pipe and flanges etc., adds an additional level of security.

Based on the foregoing review and comments, it is my opinion that the design and construction of the bulkheads were carried out adequately and that a catastrophic disruptive shear or structural failure leading to a large release of water is extremely unlikely.

It is my understanding that an extensive study of the bulkheads in the American Tunnel has been proposed. Additional study would not impact my opinions as they relate to a potential catastrophic failure of the bulkheads as defined herein. My opinions are based upon the bulkhead design criteria as provided in the original design reports, which take into consideration the potential head conditions for each of the American Tunnel bulkheads. Under those accepted conditions (which, to my knowledge, have not been questioned), a catastrophic failure of the bulkheads is extremely unlikely and additional study would not be warranted.

Stephen Phillips

#11880.

REFERENCES.

1. United States Department of the Interior, Geological Survey, Professional Report 535.

2. Sunnyside Gold Corporation. Miscellaneous communications with SGC personnel.

3. Garrett W.S. and Campbell Pitt, L.T. (1958). Tests on an Experimental Underground Bulkhead for High Pressures. Journal of the South African Institute of Mining and Metallurgy (1959). Pages 123-143.

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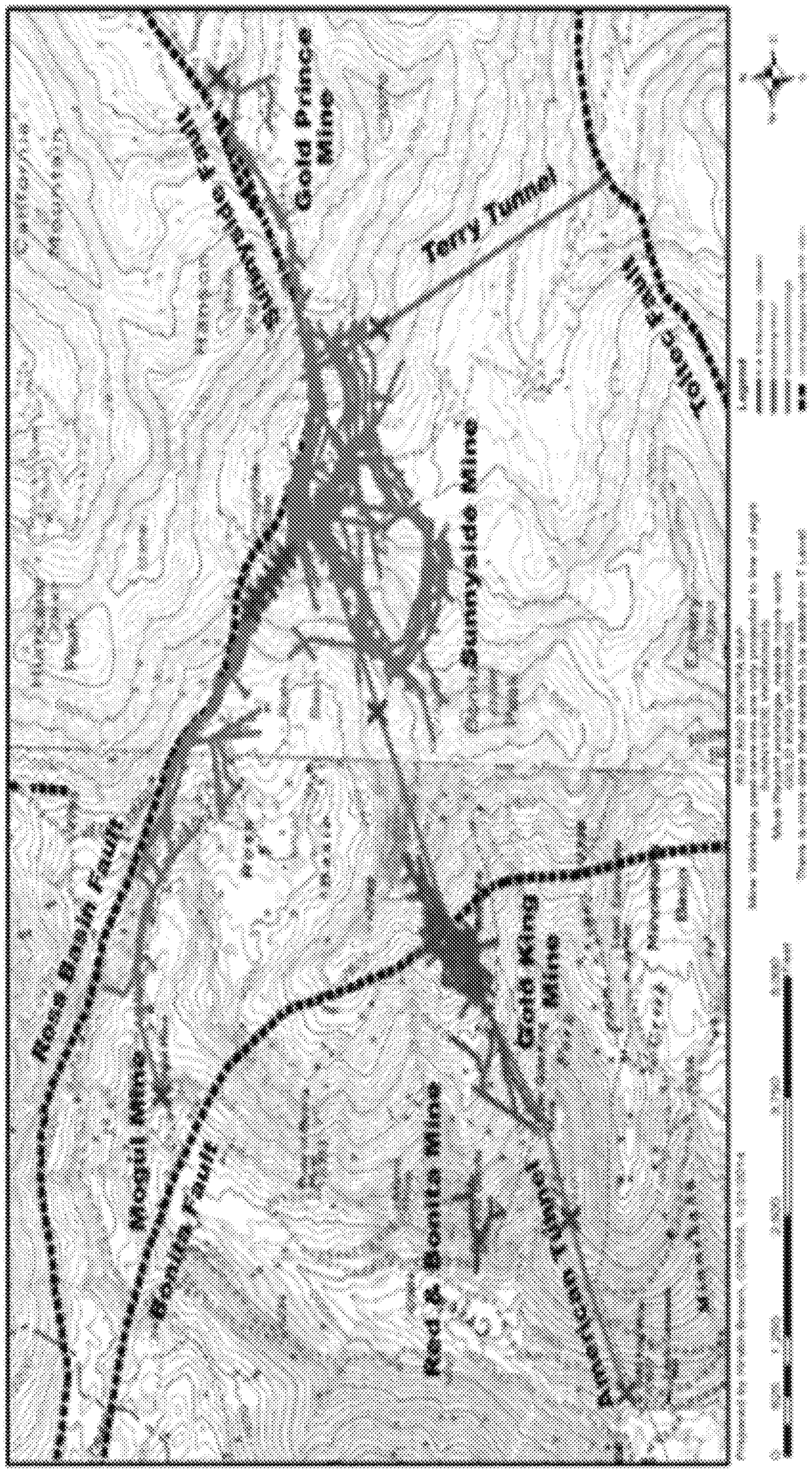
5. Lancaster F.H. (1964). Report on Research into Underground Plugs. Transvaal and Orange Free State Chamber of Mines Research Report No. 27/64.

6. Auld, F.A. (1983). Design of Underground Plugs. International Journal of Mining Engineering. 189-228

7. USGS (2014) Earthquake Hazard Program, Probabilistic Maps and Data – Western US.

ATTACHMENTS

Attachment 1



Map Showing the Surface Projection of Underground Mine Workings, Major Fault Zones and the Locations of Bulkheads (Red X's).

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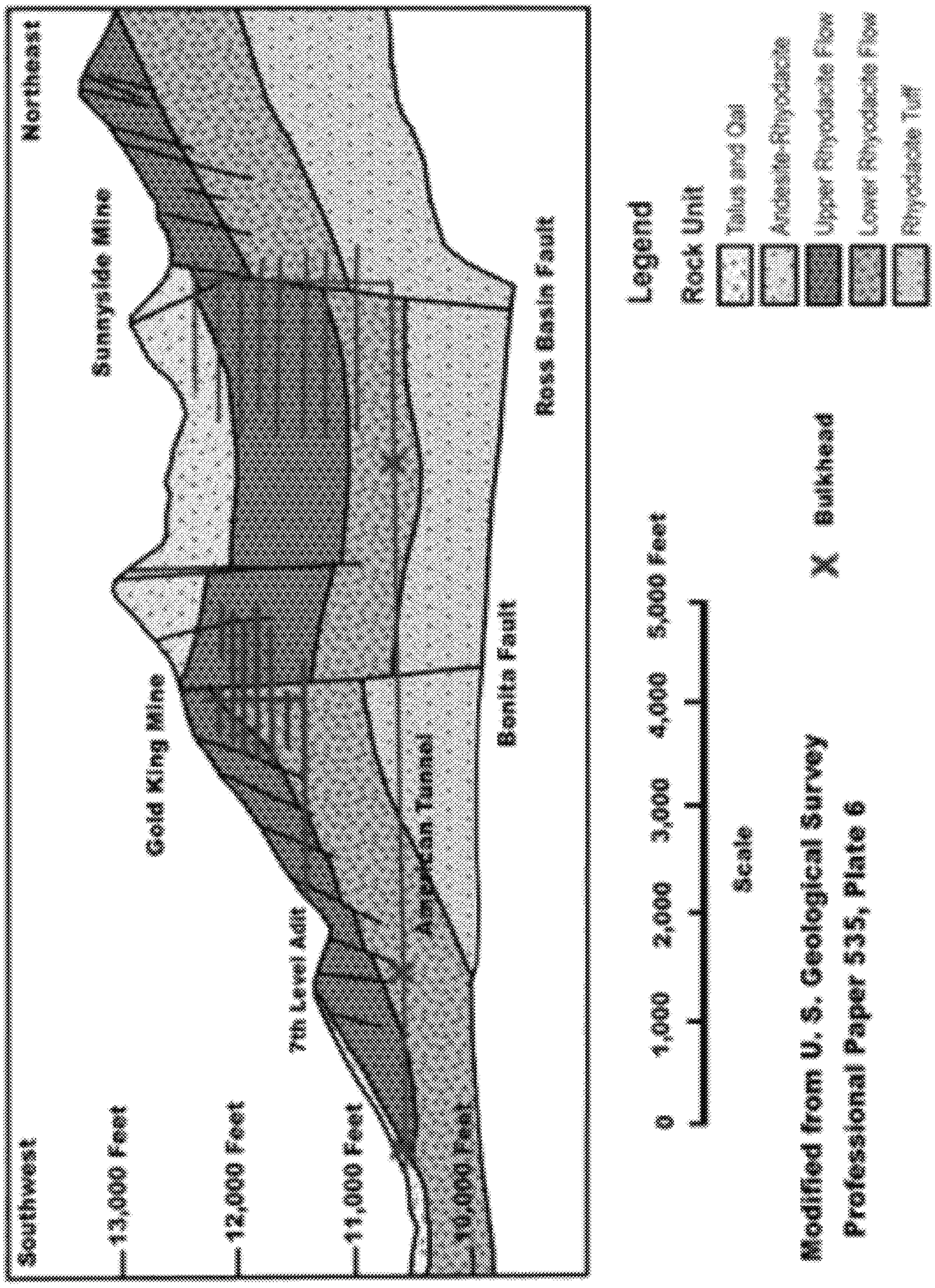
Attachment 2



Cross-Section of Gold King and Sunnyside Mines